

Motor system in voluntary movements

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Points of discussion

- Introduction
- Motor control hierarchy
- Final common pathway (Motor neurons)
- Spinal reflexes
- Length monitoring systems
- Tension monitoring systems
- Cerebral cortex
- Descending pathways
 - Pyramidal
 - Extrapyramidal
- Basal Ganglia
- Cerebellum
- Brainstem

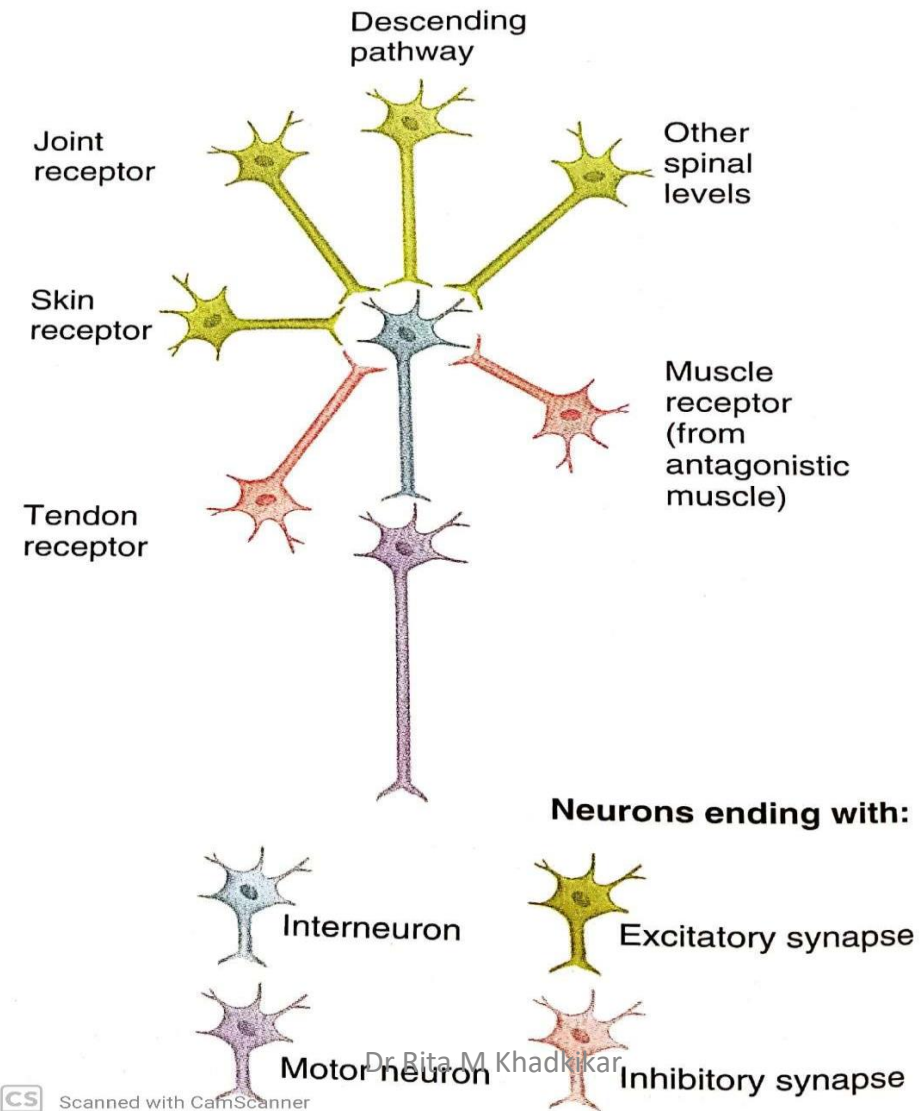
Introduction :Nervous system

- CNS and PNS
- Sensory and motor
- Motor :Somatic and autonomic

Introduction to voluntary movements

- Voluntary movements deals with control of skeletal muscle (Somatic nervous system)
- Purpose of skeletal muscle activity: locomotion, communication , maintaining balance and posture.
- The final nerve controlling the skeletal muscle is the Alpha motor neuron.
- Interneurons form 90% of spinal neurons(get input from higher level).

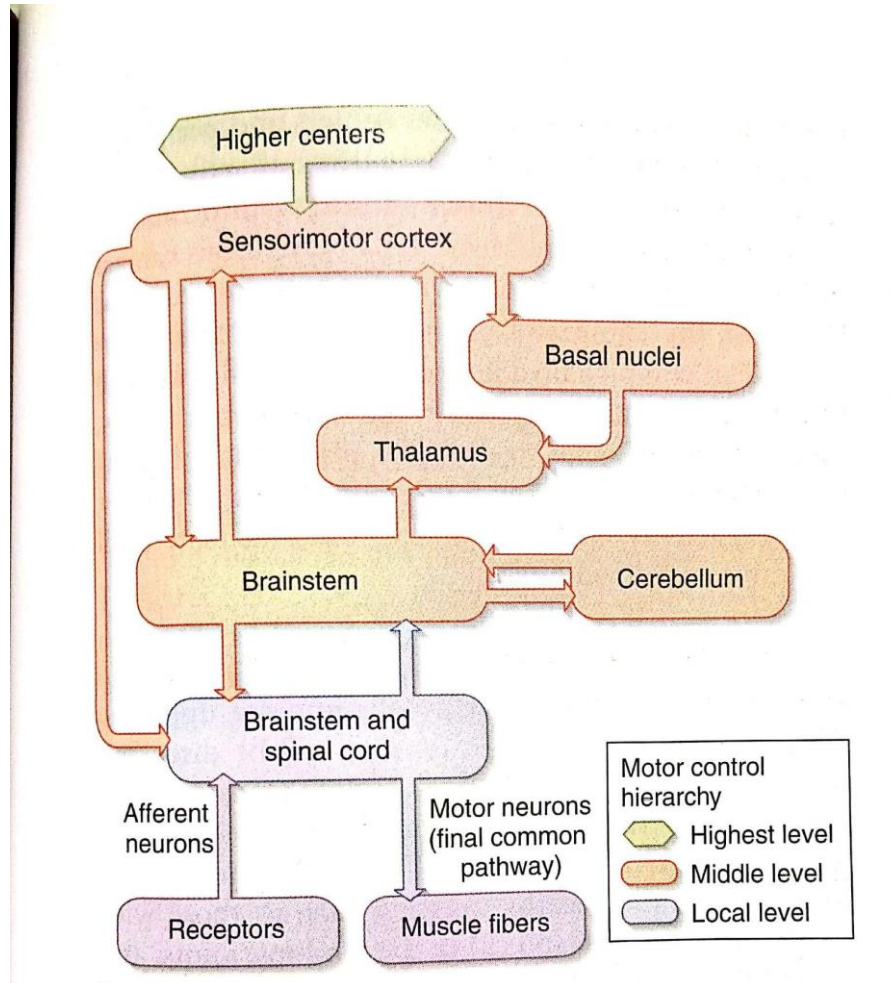
Final common pathway



Introduction to voluntary movements

- Simplest form of all these voluntary activities are reflexes.
- More complex are voluntary activities like playing an musical instrument.
- Some movements fall between these 2 categories running, walking, chewing which are voluntary in the beginning and at the end and are reflexive in between.
- Contraction of muscle can be isotonic (For movements) or isometric (for posture)

Motor system in control of voluntary movements



The conceptual hierarchical organization of the neural systems controlling body movement. Motor neurons control all the skeletal muscles of the body. Sensorimotor cortex includes those parts of the cerebral cortex that act together to control skeletal muscle activity. The middle level of the hierarchy also receives input from the vestibular apparatus and eyes (not shown in the figure).

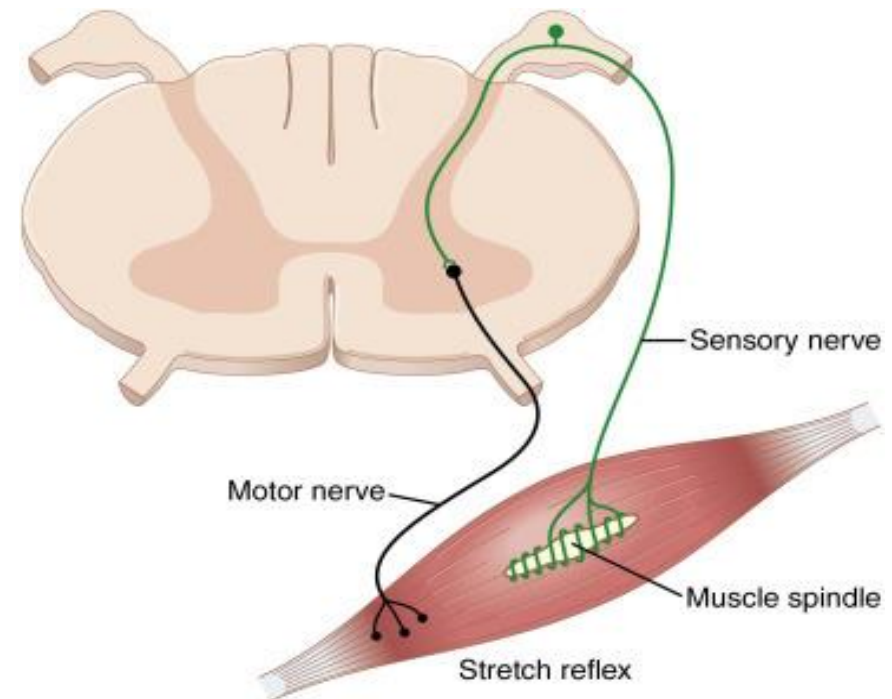
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Motor system in control of voluntary movements

- Lowest level controlling muscle activity is spinal cord
- Influenced by cerebral cortex and brainstem
- Basal Ganglia and cerebellum are giving inputs to cortex
- Sensory inputs are very important to make movements perfect .
- Ears, eyes, skin receptors, proprioceptors (muscle spindles, golgi tendon organs), vestibular apparatus are extremely essential to perform an accurate movement.

Spinal motor mechanisms

- Spinal reflexes are essential for many routine activities.
- Simplest is the stretch reflex, where the muscle when stretched responds by contracting.
- Receptors-muscle spindle
- Afferent (Ia and II)
- Efferent (Alpha motor neuron)
- Effector :extrafusal fibres



Muscle sensory system

- Muscle spindles

Are intrafusal fibres(10-12) in a capsule parallel to the extrafusal fibres.

- Intrafusal fibres are of 2 types

1. Nuclear chain (More)
2. Nuclear bag

They have a central non contractile part sensitive to stretch and a peripheral contractile part.

- 2 Afferent

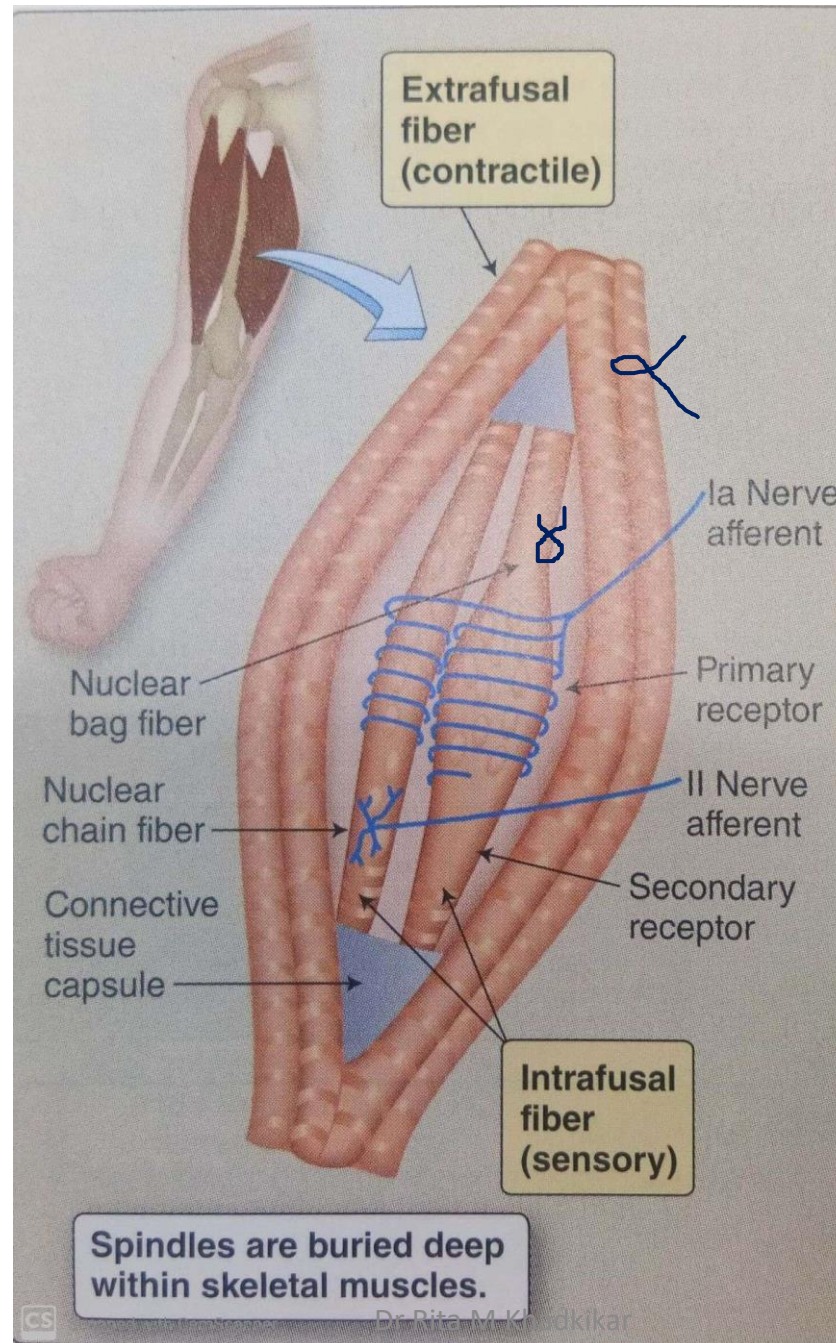
Ia from the centre of both Nuclear chain and nuclear bag fibres (**Dynamic response**-to changes in length)

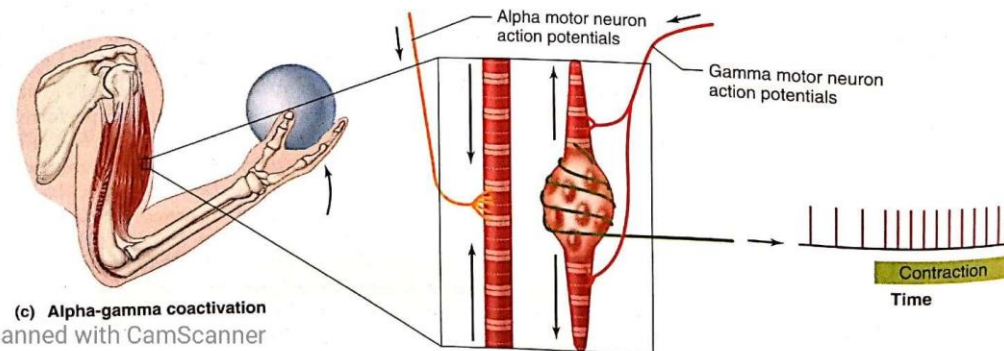
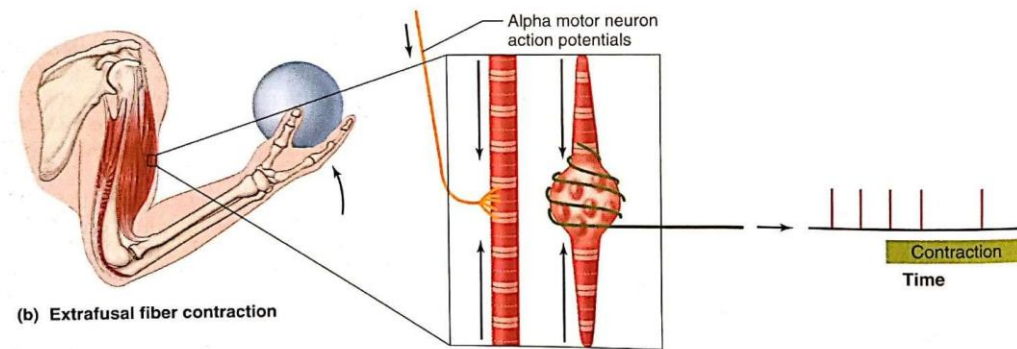
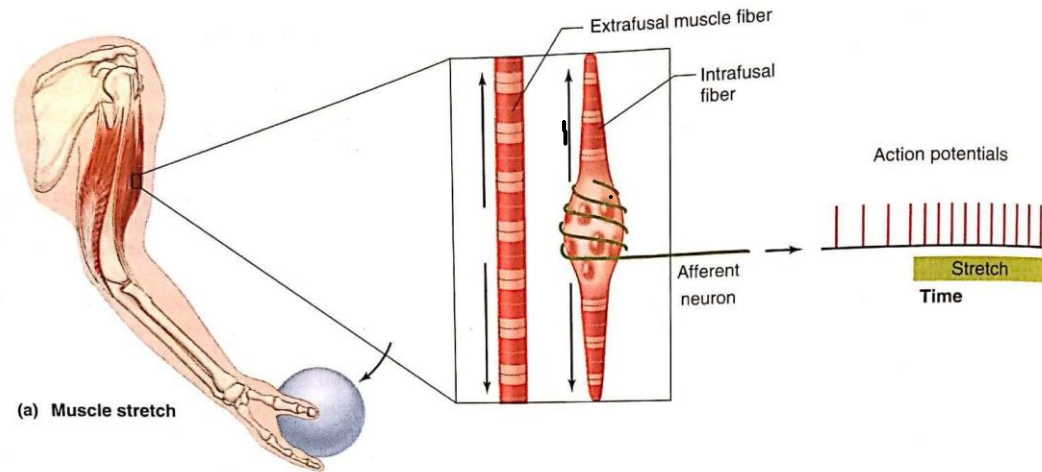
II from the Nuclear chain (**Static response**-responds to absolute length, ensures continuous discharge)

- 2 Efferent

Alpha(α) –to extrafusal fibres

Gamma (γ) - to intrafusal fibres(Peripheral portions)





Stretch reflex and Alpha (α)-Gamma (γ) coactivation

- When stretch receptors are stimulated the muscle contracts.(Monosynaptic reflex)
- This decreases stretch of muscle spindles to no input from alpha motor neuron so the muscle relaxes .
- But this is difficult if it happens in the anti gravity muscle(which need to be contacted continuously) as we will not be able to stand upright.

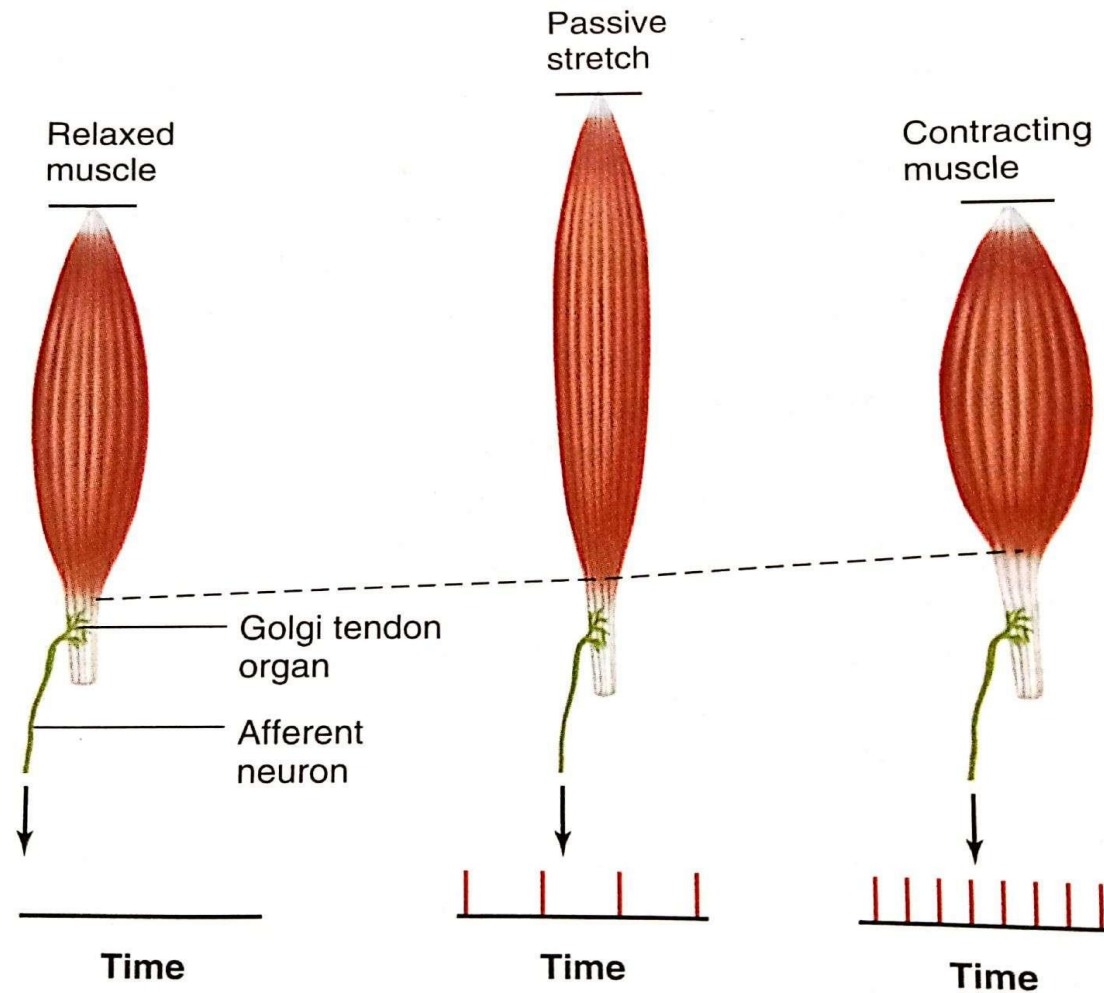
For this we have Alpha (α),Gamma (γ) coactivation

The afferents from muscle spindles enter the spinal cord and not only stimulate stretch reflex but also to go higher centres. Higher centres increase both alpha and gamma motor neuron discharge (Alpha (α),Gamma (γ) coactivation).

Alpha stimulation causes contraction of extrafusal fibres

And Gamma stimulation causes contraction of intrafusal fibres which keeps muscle spindle stretched and whole muscle remains contracted.

Golgi tendon organs

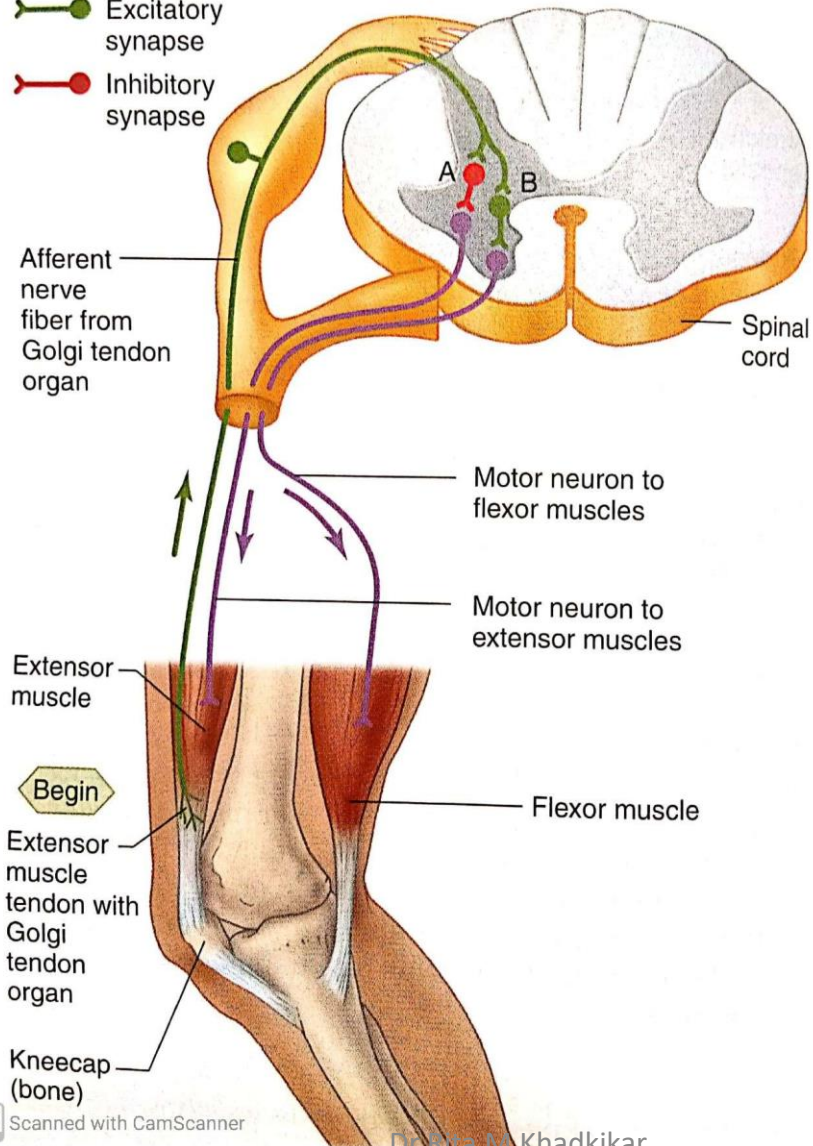


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Action potentials in afferent neurons

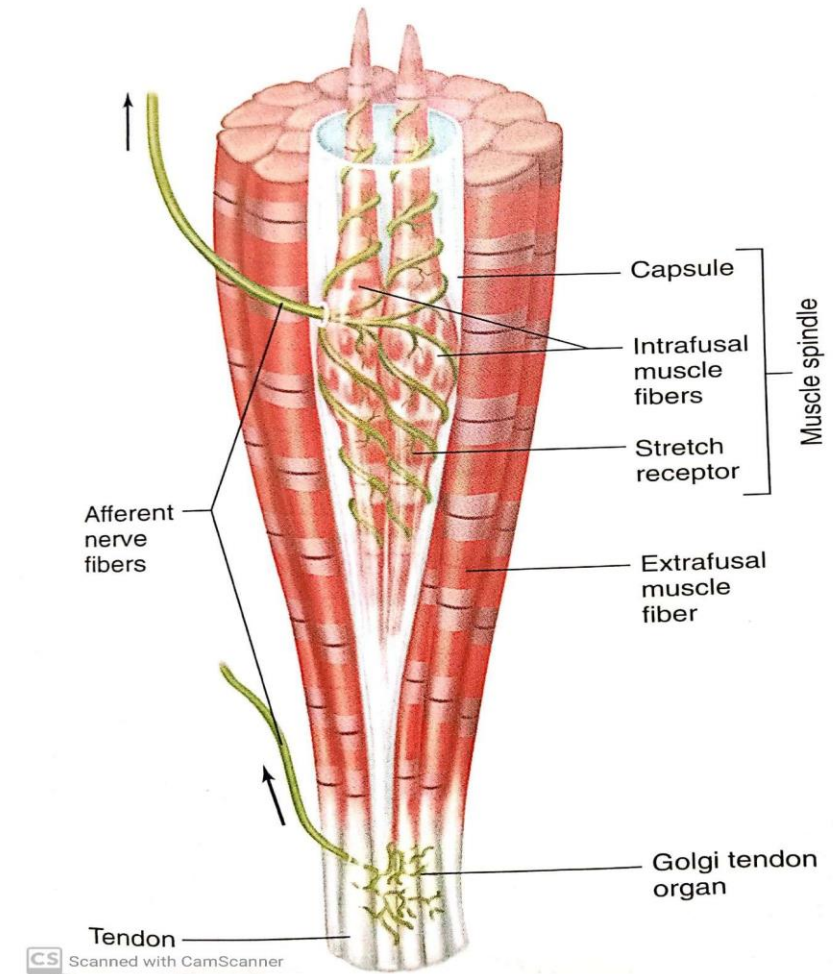
Neurons ending with:

-  Excitatory neuromuscular junction
-  Excitatory synapse
-  Inhibitory synapse

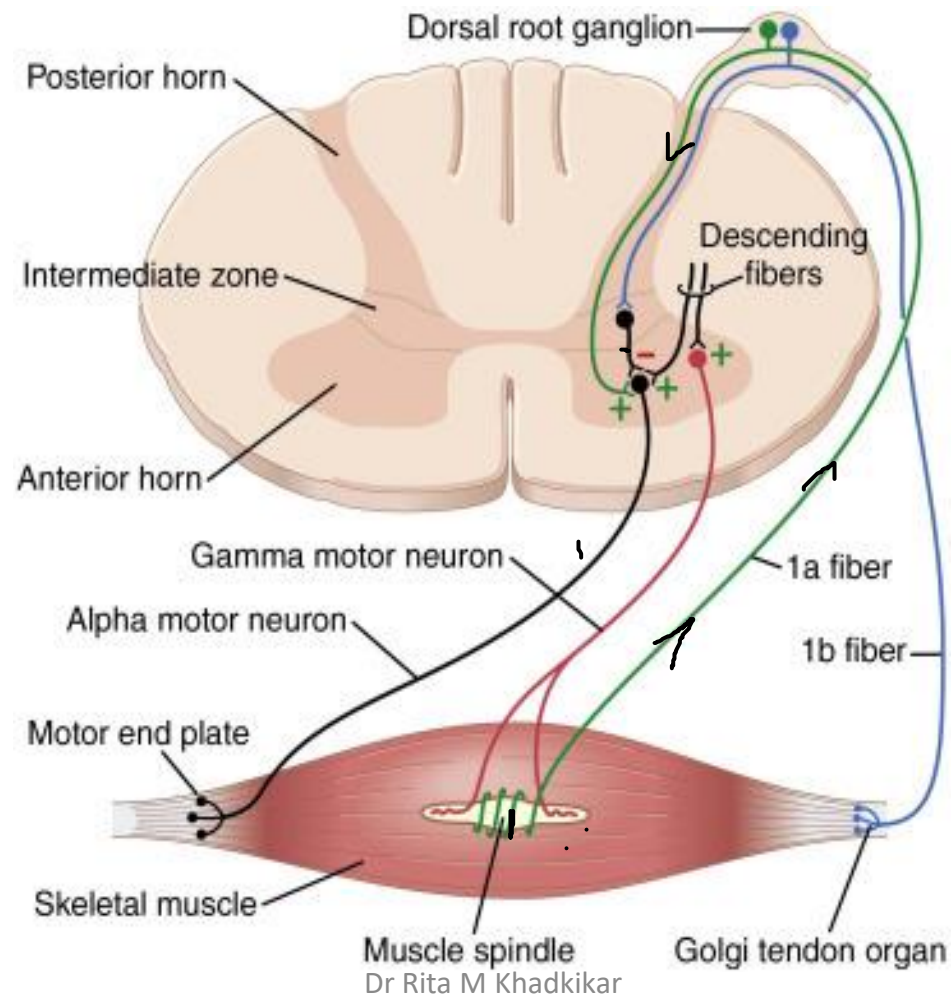


Muscle spindle and Golgi Tendon Organs(GTO)

- Muscle spindle detect change in muscle length.
- Its stimulation leads to contraction of muscle
- Golgi tendon organ detect change in tension of the muscle
- Its stimulation leads to relaxation of the muscle

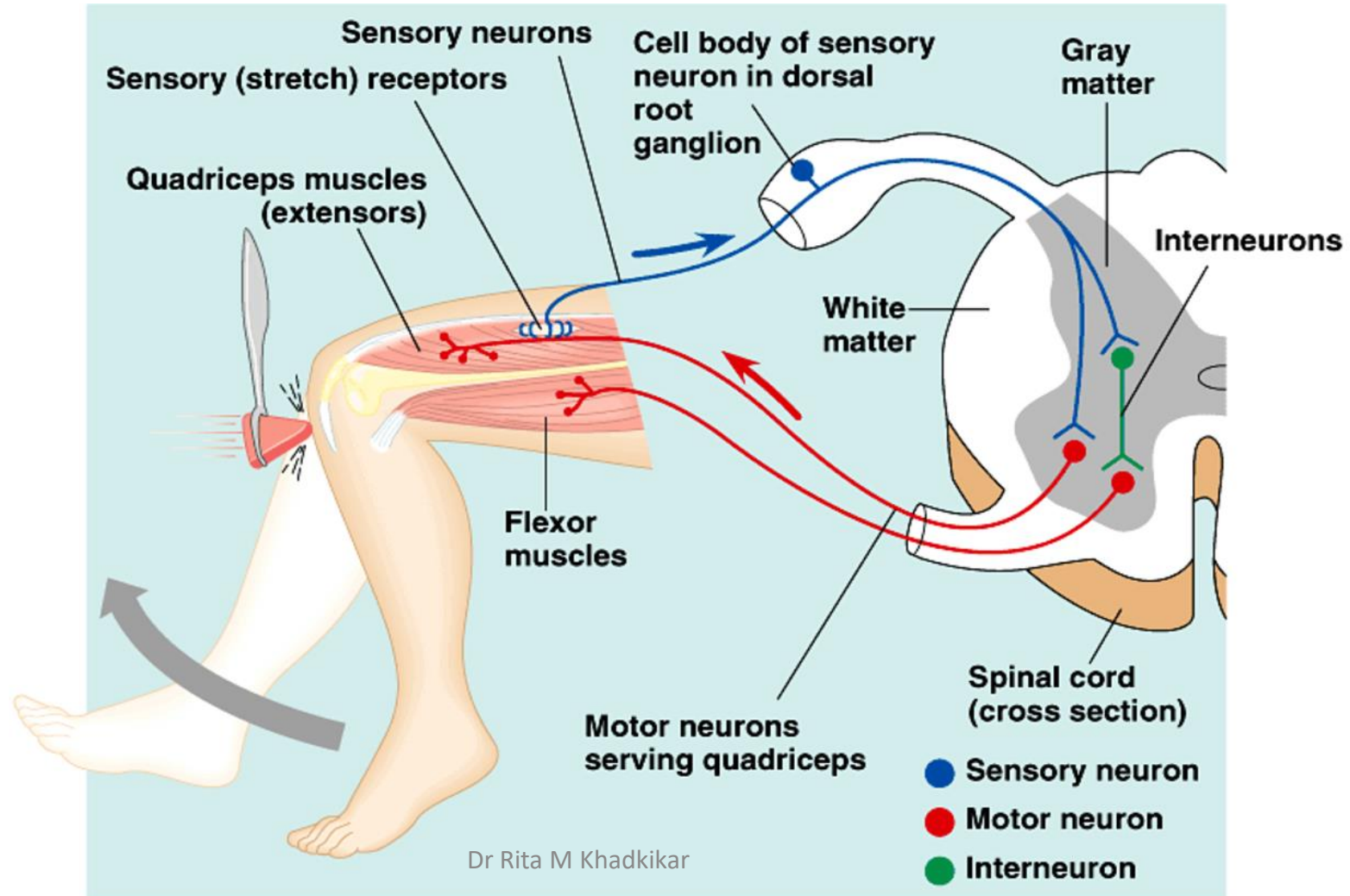


Influence on alpha motor neuron

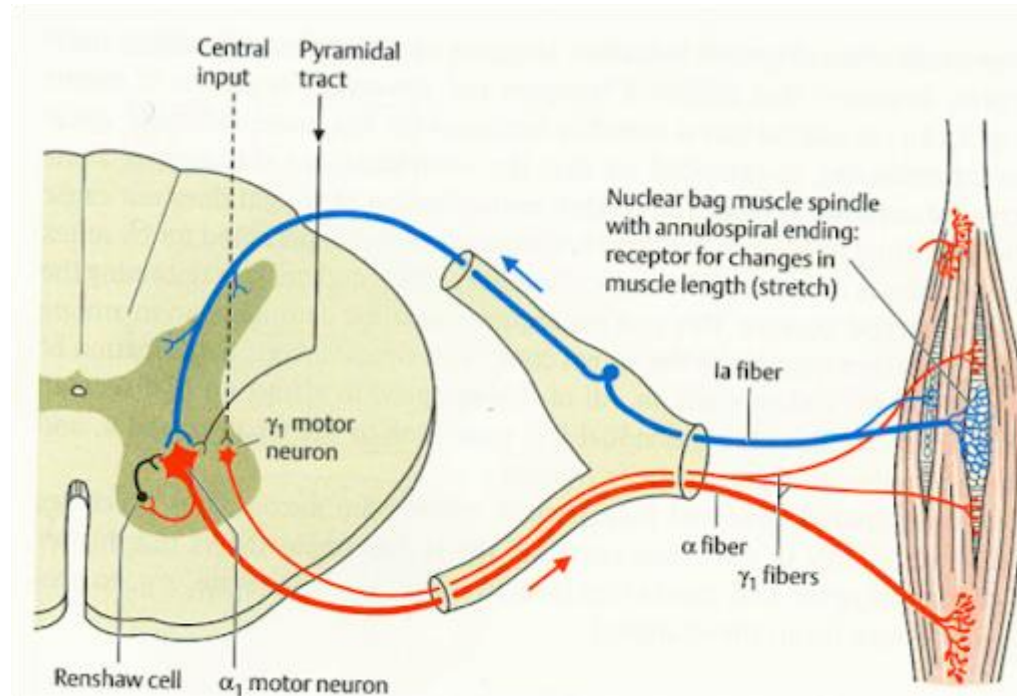


Reciprocal innervation (agonist and antagonist)

- Knee jerk



Renshaw cell inhibition of alpha motor neuron



Neurons ending with:

-  Excitatory neuromuscular junction
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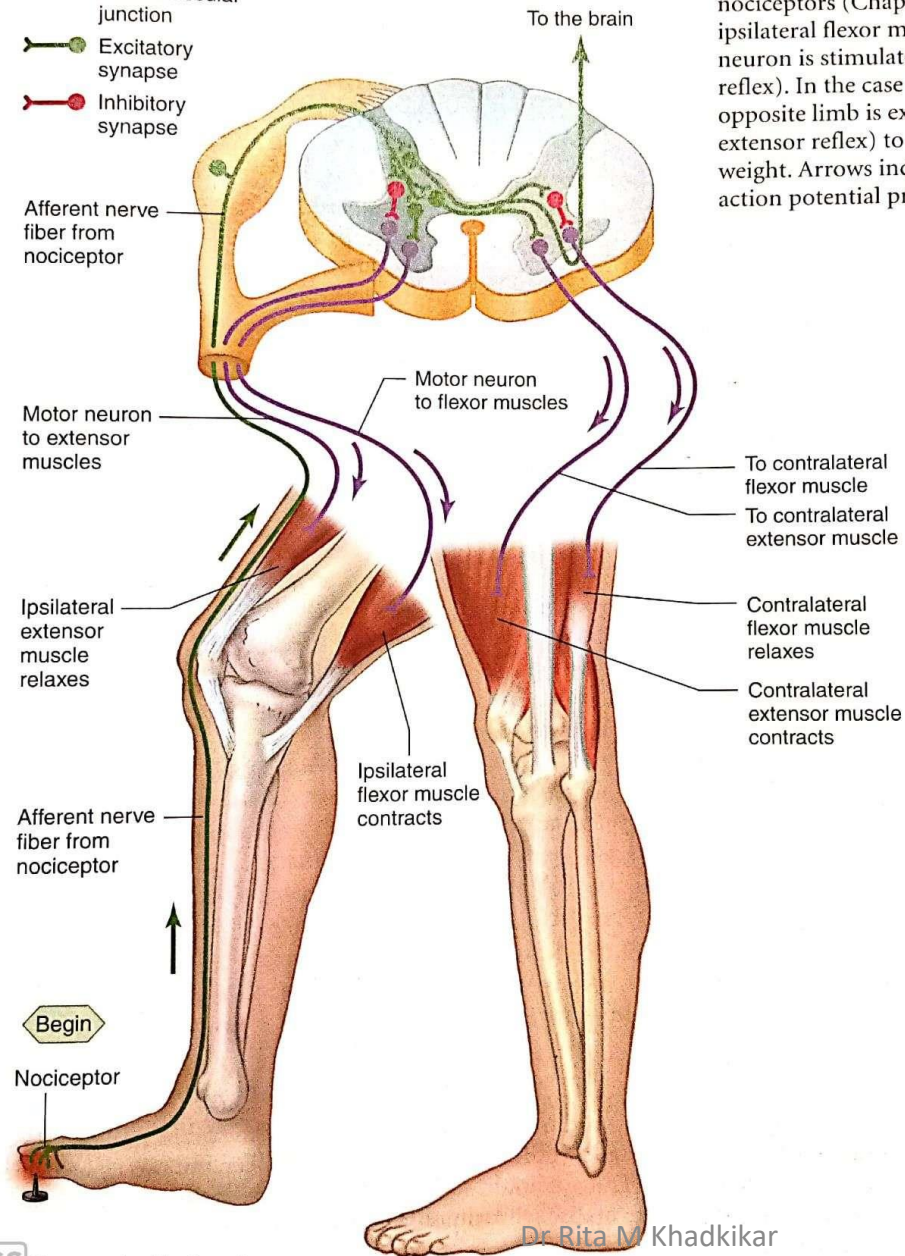


FIGURE 10-9

In response to pain detected by nociceptors (Chapter 7), the ipsilateral flexor muscle's motor neuron is stimulated (withdrawal reflex). In the case illustrated, the opposite limb is extended (crossed-extensor reflex) to support the body's weight. Arrows indicate direction of action potential propagation.

Spinal shock

- Paralysis and loss of sensations below the lesion .
- Lasts from 2weeks to few months . (few minutes in the frog)
- Slowly the reflexes are regained and may be exaggerated due to loss of inhibition of higher centres.

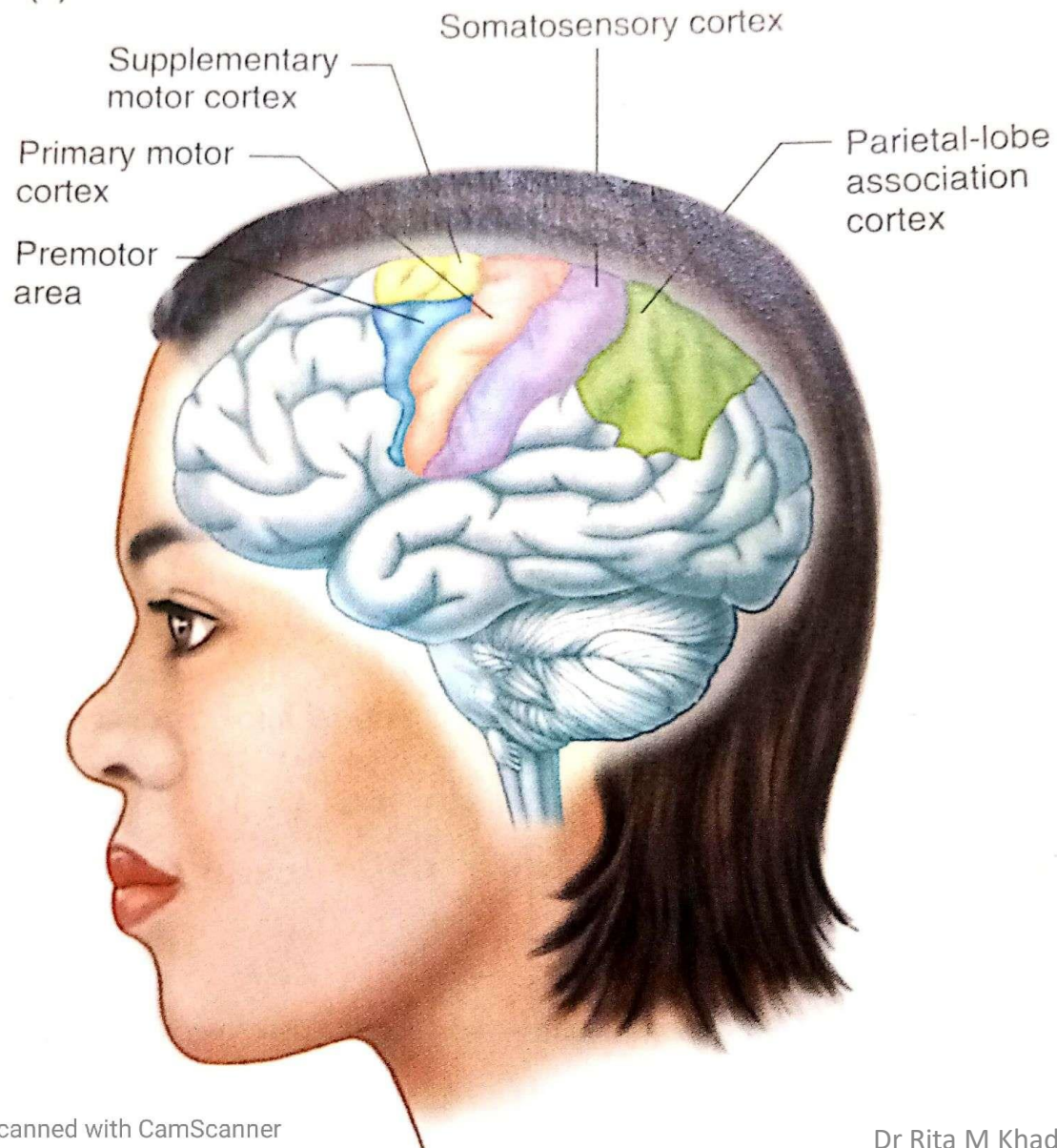
Cerebral cortex

All sensory impulses like vision, hearing ,proprioception , balance ,touch from from the body reach the sensory cortex (Area 3,1,2) .

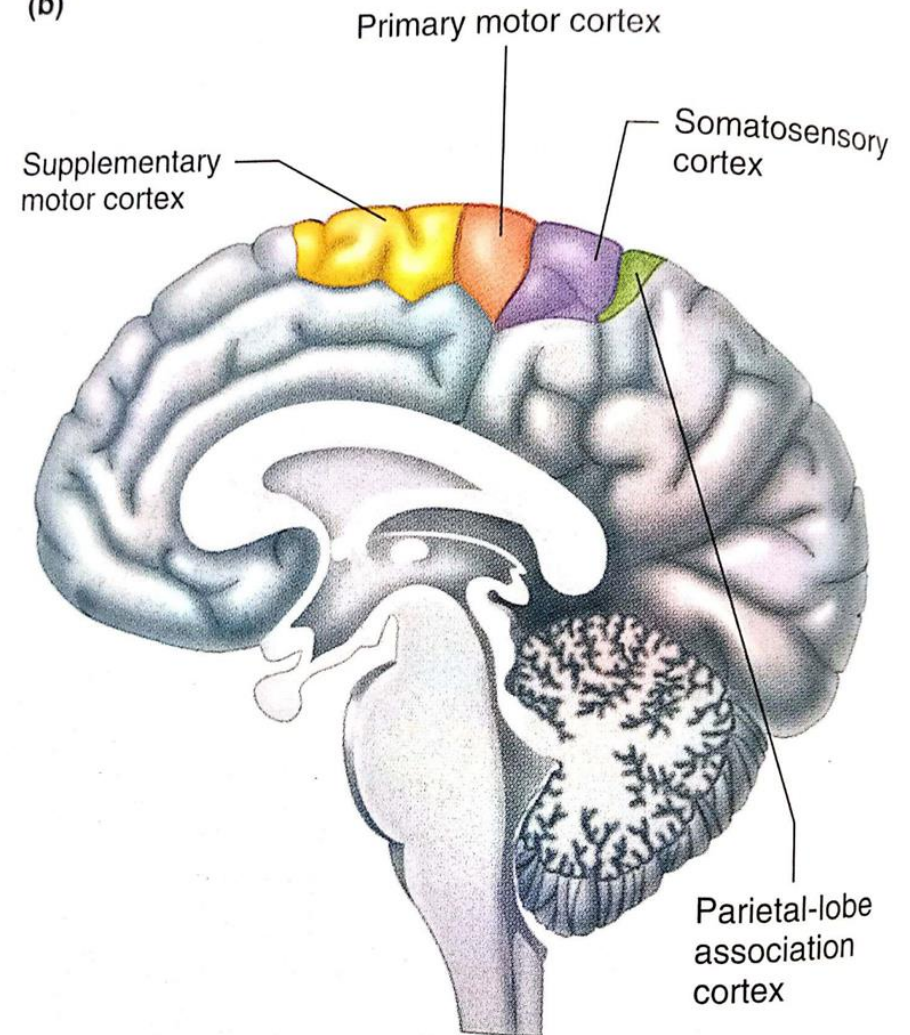
Association areas integrate all this information and send it to the motor, premotor and supplementary motor areas.

Premotor and supplementary motor areas help plan the movement.

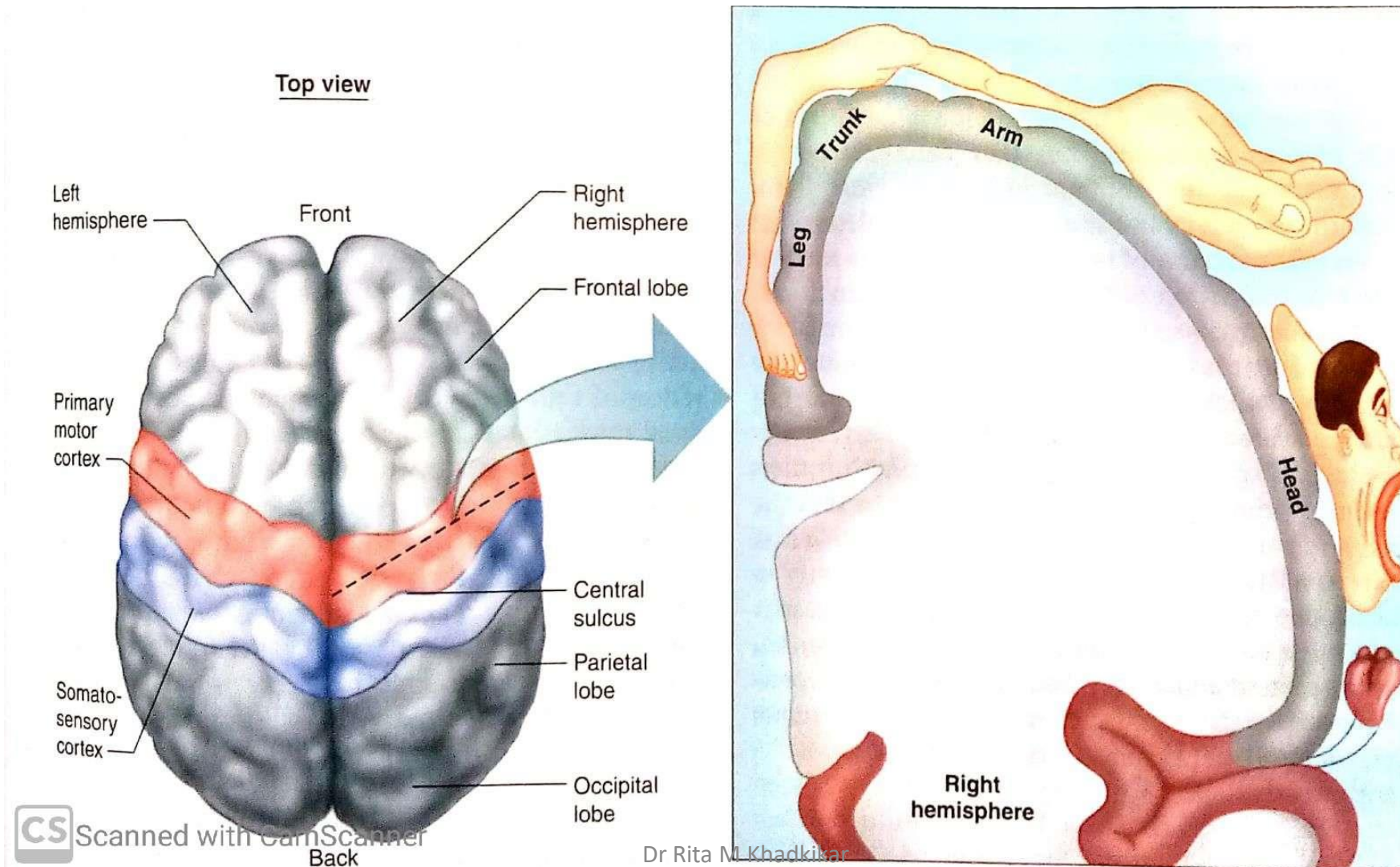
(a)



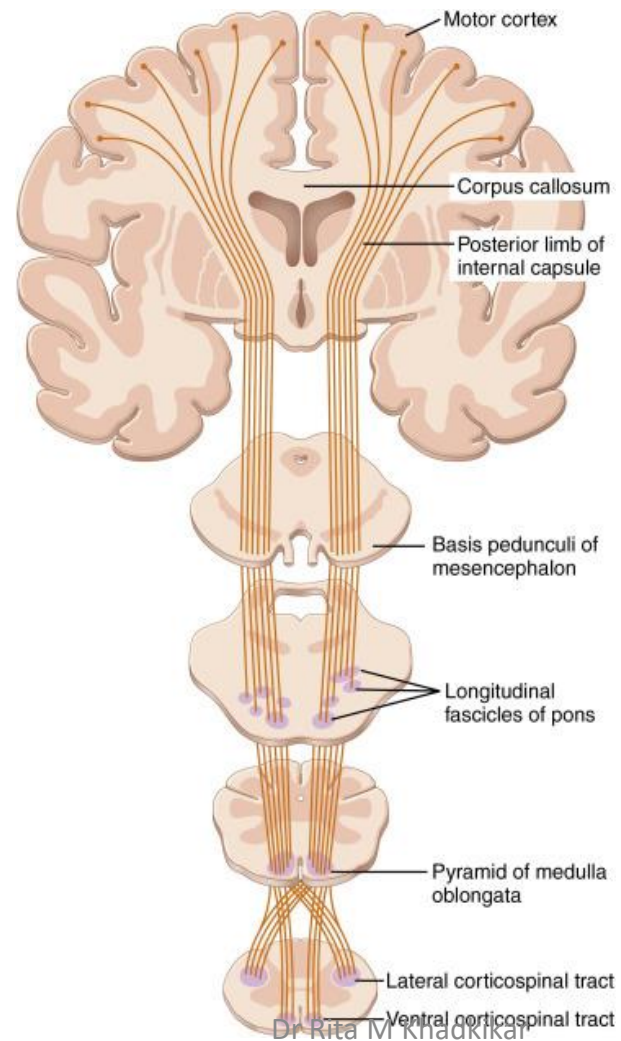
(b)



Motor Homunculus



Corticospinal tract



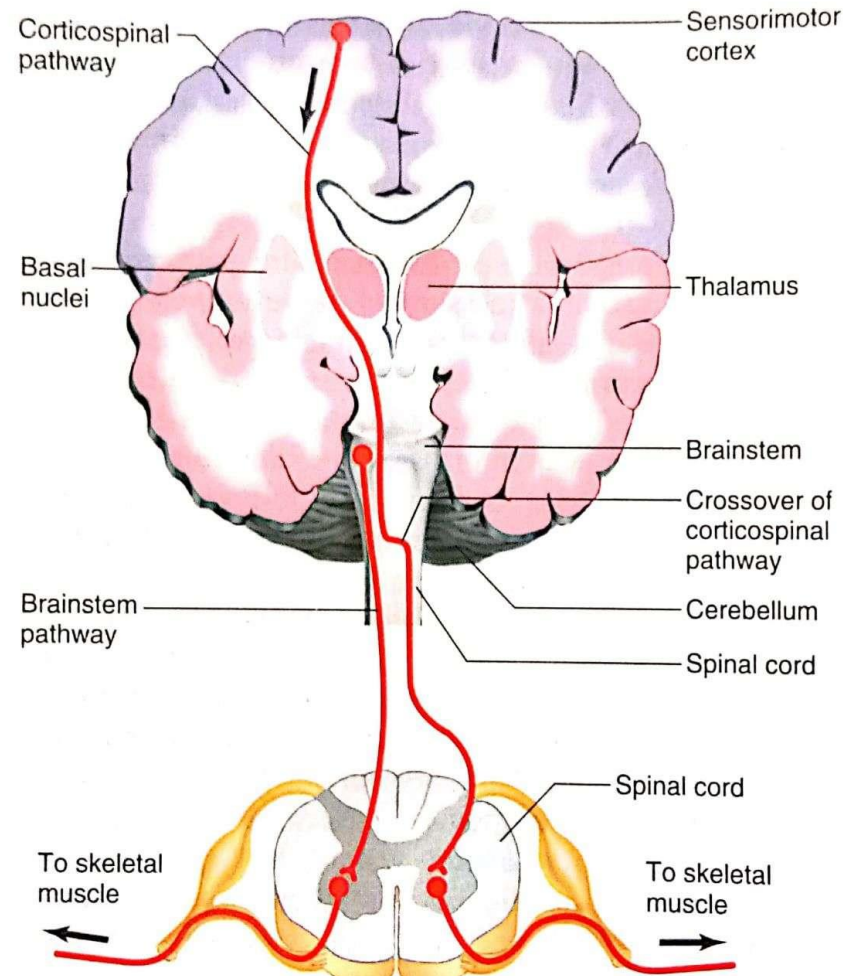
Pyramidal and extrapyramidal tract

- Corticospinal and corticobulbar fibres (head and neck region) control the muscles on the opposite side of the body.
- Extrapyramidal control muscles on the same side of the body

Ex:

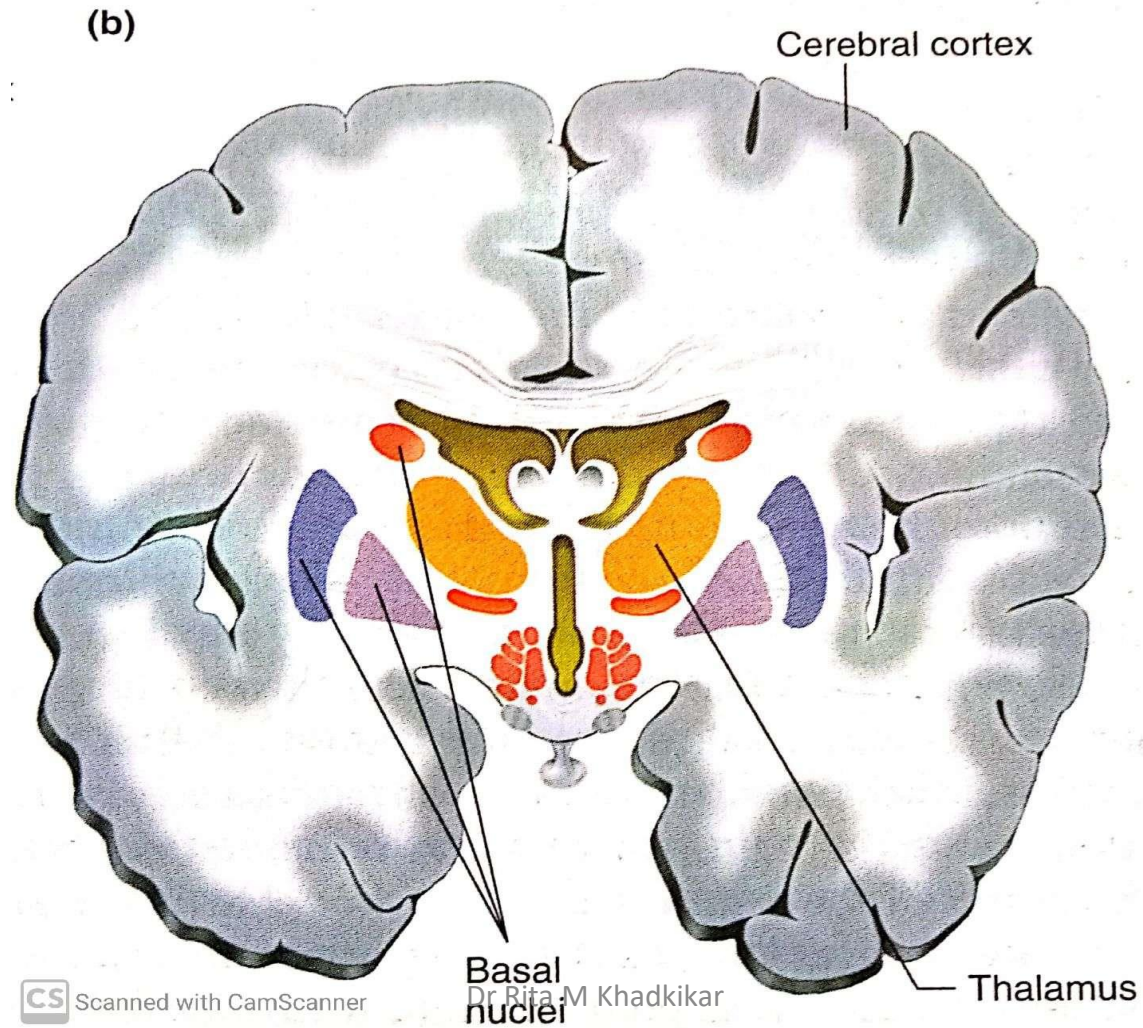
- Reticulospinal
- Vestibulospinal
- Rubrospinal
- Tectospinal

Pyramidal and extrapyramidal tract



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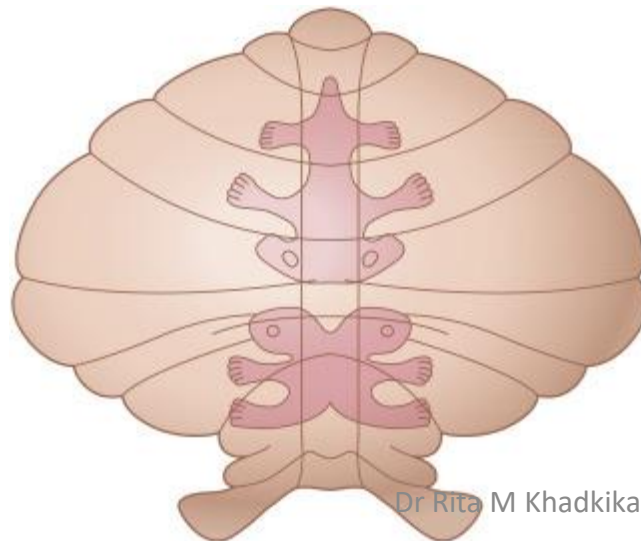
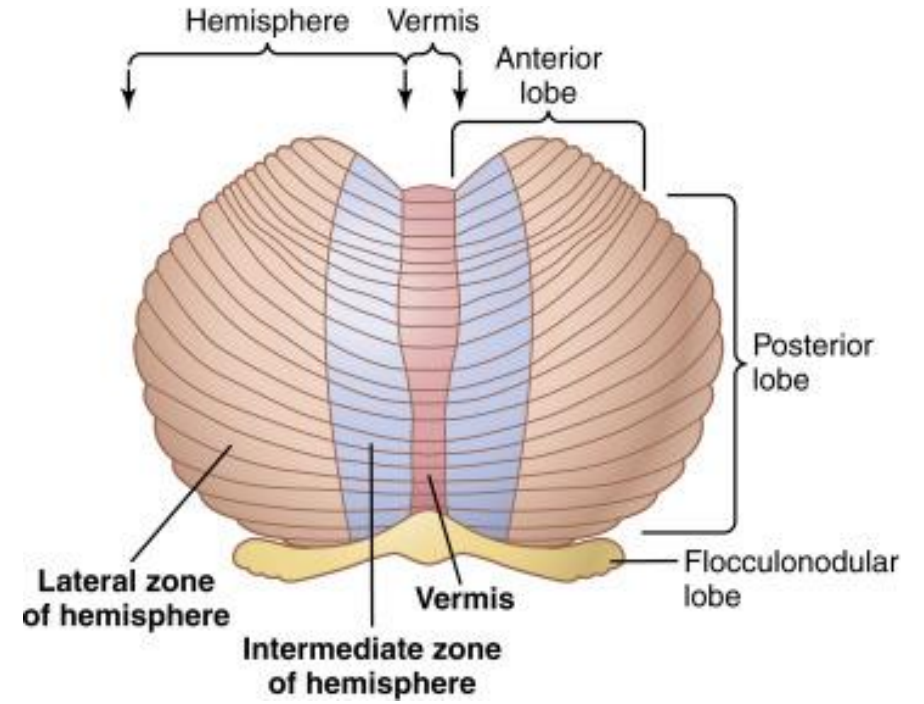
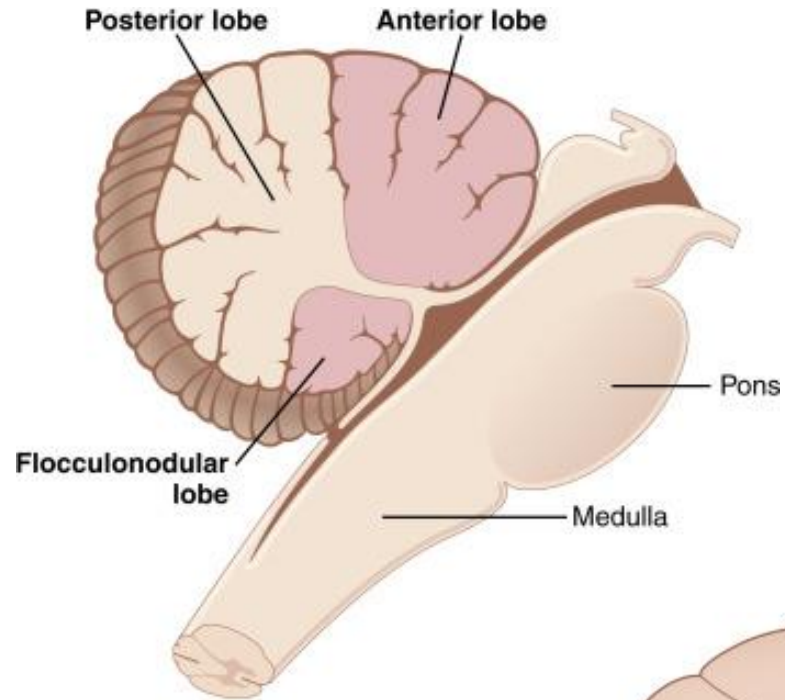
Basal Ganglia



Basal Ganglia

- It gets impulses from cortex and through the direct and indirect pathway it facilitates or inhibits the cortex through the thalamus.
- For planning the pattern and sequence of movements
- Comparing the intended and actual movement .

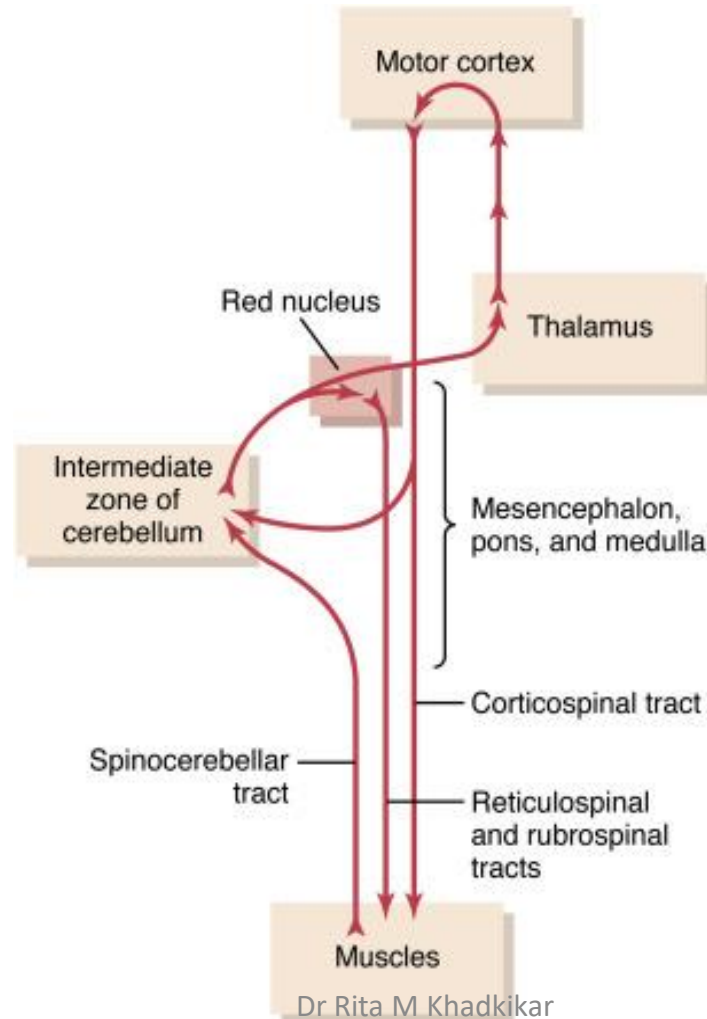
Cerebellum



Cerebellum

- Cerebellum acts through the cortex or brainstem
- It helps in planning and also in refining the ongoing movement.
- It brings about precise and coordinated movements .(ex:eye, hand)
- Its lesions cause ataxia (loss of coordination)

Cerebral and cerebellar control of Muscle



Intentional tremors

- Ataxia
- Dysarthria
- Intentional tremors

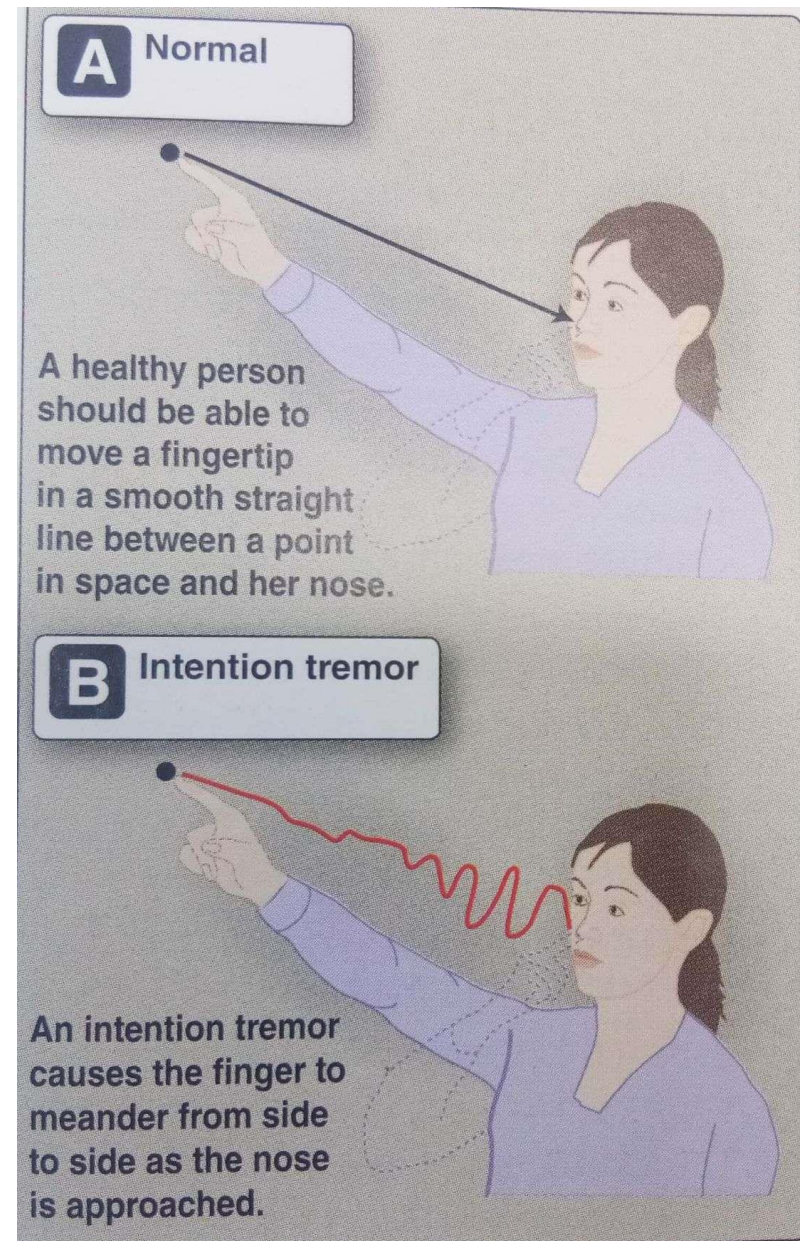
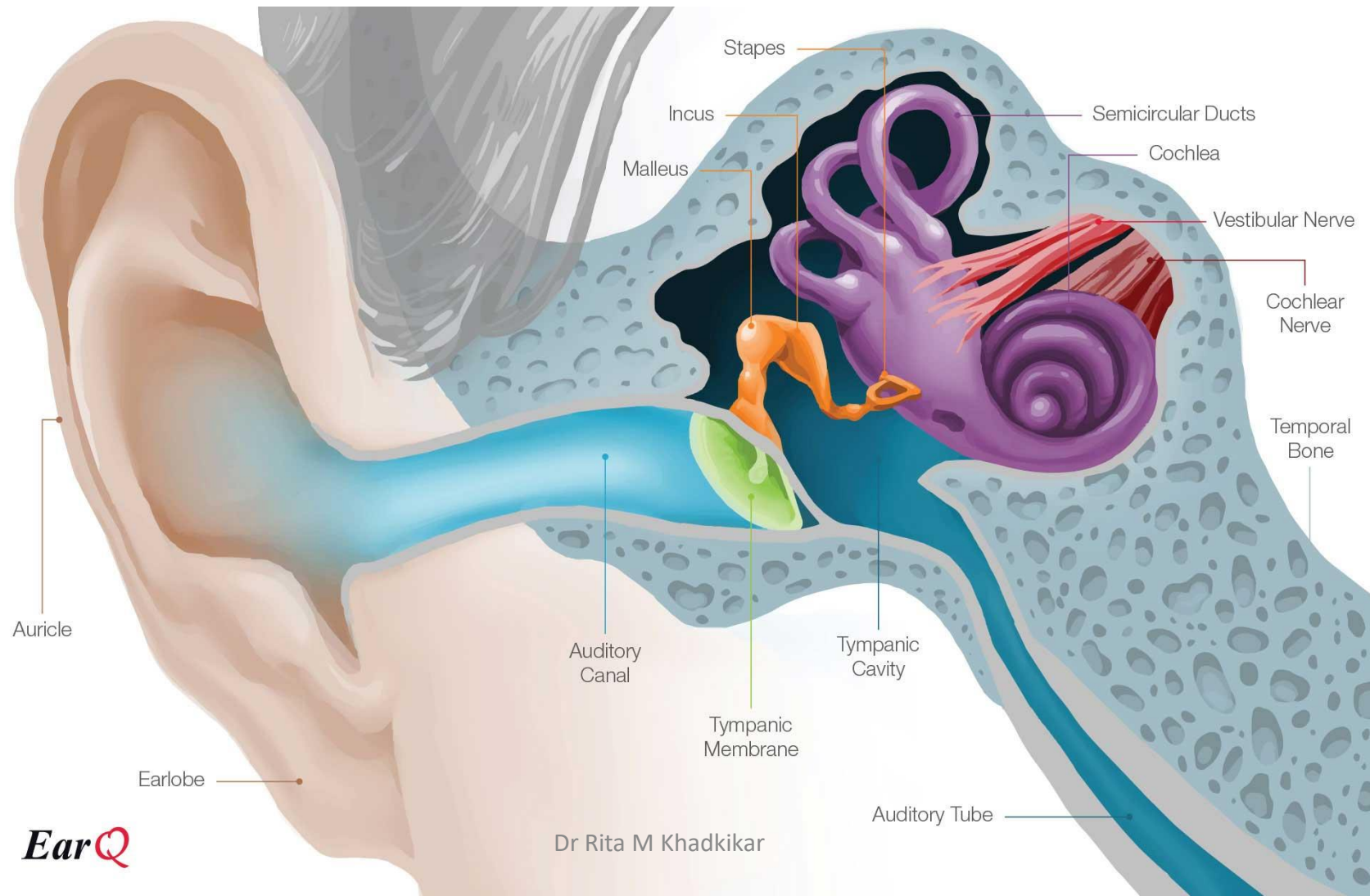


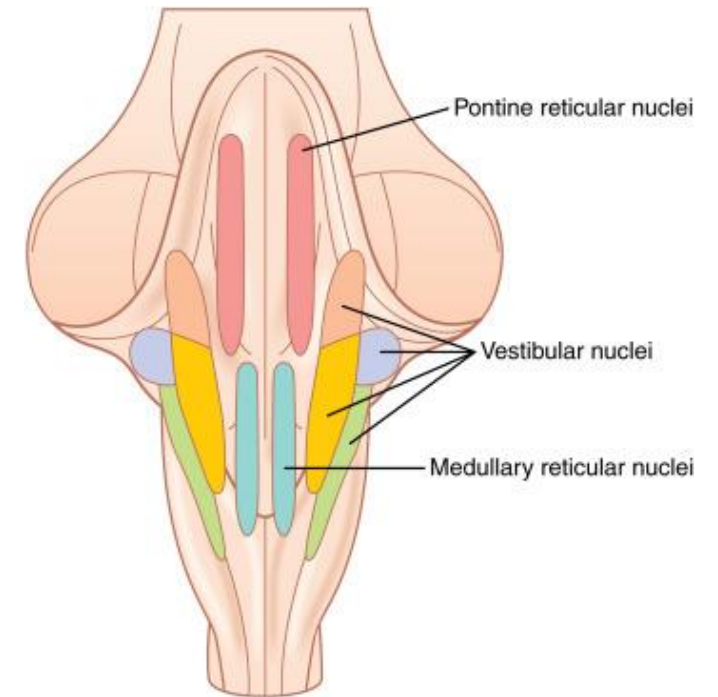
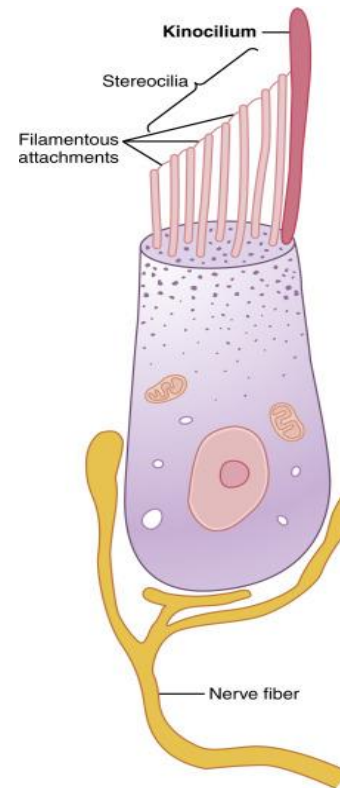
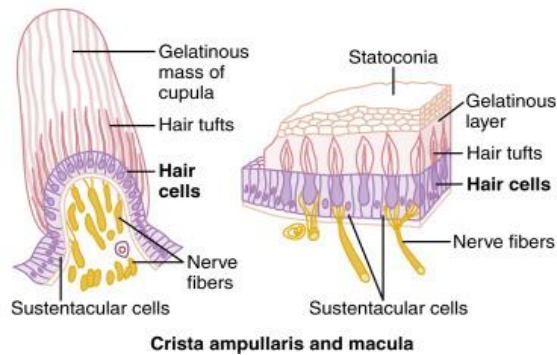
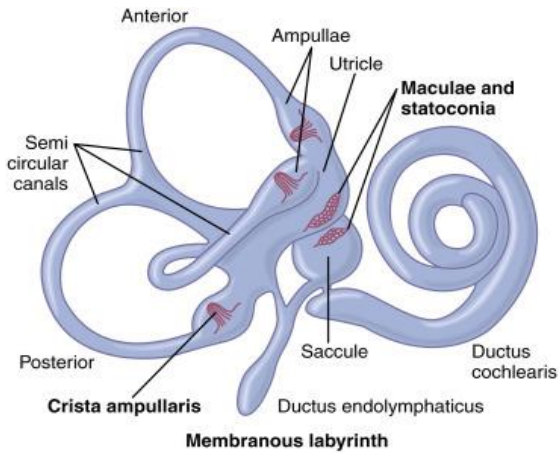
Figure 11.14
intention tremor.

Vestibular apparatus



Vestibular apparatus

(sensory input to brainstem and cerebellum)



Brainstem motor control centres

- Superior colliculus :controls head and neck movements through tectospinal tract.
- Red Nucleus of Midbrain controls upper limb through rubrospinal tract
- Reticulospinal and vestibulospinal tracts control both upper and lower limbs.

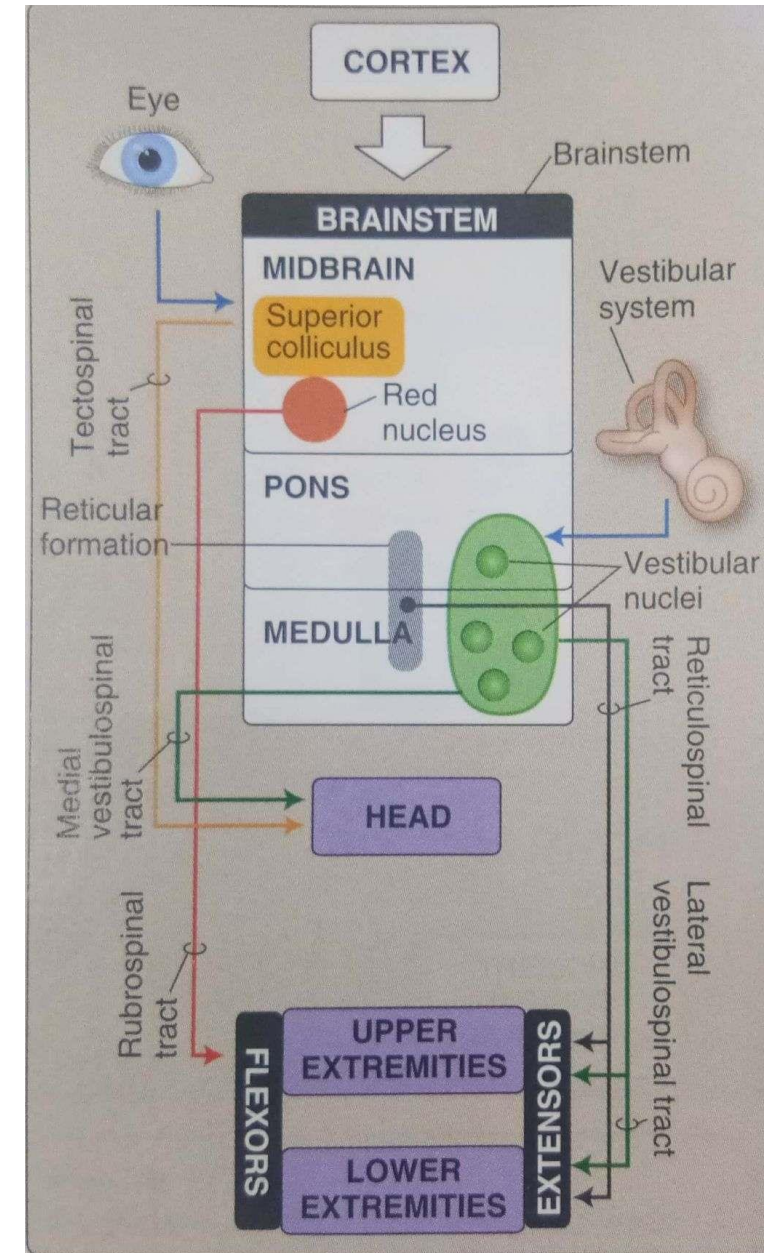


Figure 11.15

Summary

- Final common pathway to muscles is alpha motor neuron which has both excitatory and inhibitory influences.
- Spinal reflexes are important for all the voluntary activities.
- Higher centres influence the spinal reflexes.
- Spinal shock and damage to the higher centres affect the smooth conduction of voluntary movements.

Thank You